

Developing a Product Line Acquisition Strategy for a DoD Organization: A Case Study

John K. Bergey
Wolfhart B. Goethert

April 2001

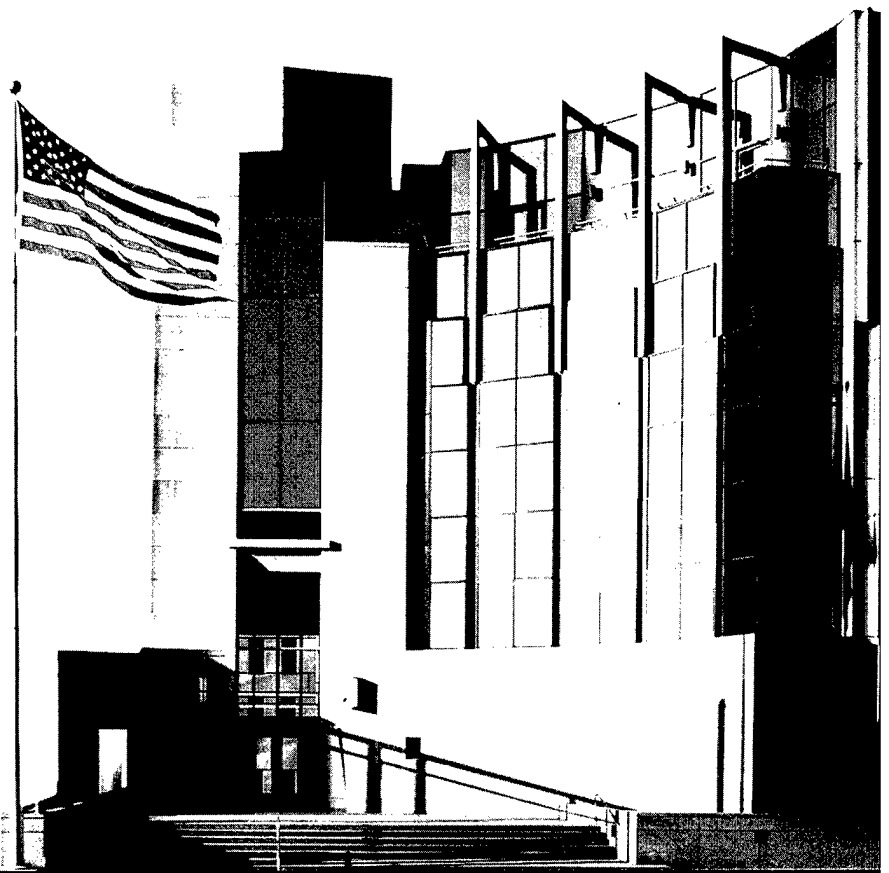
Product Line Practice Initiative

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About the Technical Note Series on Business and Acquisition Guidelines

The Product Line Systems Program is publishing a series of technical notes on product line acquisition and business practices for the DoD acquisition manager and practitioner. Each technical note will focus on one aspect of adopting software product line practice in the Department of Defense. Our objective is to provide practical guidance to early DoD adopters on ways to integrate sound product line practices into their acquisitions. By investigating and reporting best commercial and government practices, the SEI is covering new ground in overcoming the challenges and increasing the understanding, maturation, and transition of software product lines.

This series of technical notes will lay down a conceptual foundation for DoD product line business and acquisition practices that are consistent with the product line framework of the SEI [Clements 00].

While we intend each technical note to be distributed and read as a standalone document, a brief overview of software product lines is provided in *Software Product Lines: A New Paradigm for the New Century* [Clements 99]. If you are not familiar with this introductory material, we recommend you read it before reading this technical note. Other information from the SEI on product line practices, including the latest version of the *Framework for Software Product Line Practice*, is available at http://www.sei.cmu.edu/activities/plp/plp_init.html.

Acknowledgements

We want to acknowledge the contributions of Dennis Smith and Sholom Cohen who were part of the acquisition team that helped facilitate the development of the product line acquisition strategy. We would also like to acknowledge the contributions made by the members of the SPO staff and representatives from the operational units.

Abstract

Industrial experience clearly demonstrates that a product line approach for software-intensive systems can save money and result in faster time to field higher quality systems. Many within the DoD recognize the benefits of product lines, but also recognize that there are significant challenges to adopting such an approach. One of several challenges that confront a DoD organization is developing and implementing a suitable acquisition strategy. To be effective, the DoD organization must balance its product line aspirations against the ability of potential contractors (having varying levels of product line experience and “hands-on” knowledge of related legacy systems) to meet its needs. It also must balance them against the requirements of DoD policy and regulatory documents that govern the entire acquisition process.

Several key questions are: “What does developing an acquisition strategy involve?” and “How does a DoD organization develop an effective strategy for acquiring a software product line?” This case study focuses on a recent effort that shows how one DoD organization answered these questions.

This technical note describes the approach a DoD organization used to develop alternative acquisition strategies and analyzes the pros and cons of each. It summarizes the acquisition context. It also presents a number of alternative product line acquisition strategies, a method for comparing the merits of each approach, and some risk reduction measures. Although this case study purposely disguises the actual organization and product line, it reflects the considerations involved in developing a software product line acquisition strategy.

1 Introduction

Software product lines represent a new way of developing a related set of software systems. In contrast to building systems one-at-a-time, in a stand-alone manner, the practice of building sets of related systems from common software assets can yield remarkable quantitative improvements. These improvements may be measured in terms of productivity, time to market, product quality, and customer satisfaction [Clements 00].

In this case study, we examine a DoD organization that is struggling to upgrade existing stove-piped avionics systems. Rising software maintenance costs and the increasing obsolescence of its legacy computing platforms (embedded in these systems) are stymieing the organization's ability to implement new mission capabilities and enhancements at a reasonable cost. Rather than continue to maintain separate development programs for each avionics system, the organization sees consolidation of software development and maintenance into a single product line as a means to accomplish several business goals:

- Reduce development and maintenance costs.
- Increase reliability and quality of fielded products.
- Ease the integration of new computing platforms and interfaces.
- Enable faster implementation of new capabilities and system enhancements.

In this technical note, we describe how a DoD organization developed an acquisition strategy to commission a software product line¹ for a family of integrated avionics systems. We have disguised the identities of the DoD organization and the legacy system contractors to protect the privacy of all those involved. We will simply refer to the DoD organization as the "SPO" and the product line being acquired as the DoD Avionics Software Product Line or DoD "ASPL."

In Section 2, we provide background information on the SPO's legacy system environment to set the context for their product line acquisition. Next, we describe the approach that the organization used for developing and analyzing alternative acquisition strategies. Following this, we describe relevant planning assumptions, five candidate acquisition strategies, the methodology used for analyzing them, and the results. An example plan-of-action for implementing one of these acquisition strategies is presented next, along with a means for reducing the acquisition risk. Last, we provide a summary with conclusions.

¹ A software product line is a set of software-intensive systems sharing a common, managed set of features that satisfy the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way.

2 Legacy System Context for Acquiring a Product Line

The SPO has software life-cycle responsibility for three functionally related systems. The SPO envisioned creating a software product line to replace the legacy software of the three systems under their purview. We will refer to these systems as "System A," System B," and "System C." The avionics software for these systems and their variants corresponds to the future products in the ASPL.

Table 1, which is an excerpt from the product line scoping¹ report, characterizes these future software products in terms of their high-level commonality and variability.

Table 1: Future Products in the DoD Integrated Avionics Software Product Line

System Version	Software Product Characteristics
System A	Full set of interfaces; 80% of all features within product line scope
System B, Variant 1	80% of interfaces; 60% of all features within product line scope
System B, Variant 2	Same interfaces as System B, Variant 1; all features of System B, Variant 1, plus features within product line scope not in System A
System C	40% of interfaces; scaled back version of System B, Variant 2

Each instance of the DoD ASPL would be a software product that provided

- a set of integrated services that encompasses flight management, communications, navigation, and display capabilities
- the ability to insert new technologies across platforms significantly faster and more cost effectively
- the means for efficient system integration and increased functionality with minimal impact on the baseline operator interface

As indicated in Table 1, all the systems deliver very similar capabilities to users. They differ, however, along several variation points corresponding to the legacy computing system

¹ Scoping bounds the product line by identifying the commonality that products share and the ways in which the products vary within the product line.

platform, the number of features they provide, and the number and types of external interfaces.

By exploiting the commonality of the avionics requirements across these three classes of systems, the SPO can significantly reduce software development costs and technical risk. The SPO can also reduce the time and effort needed for test and integration, scheduling, logistical support, and training.

Two companies are currently under contract to the SPO for software maintenance and enhancement of these legacy systems. One company is responsible for legacy System A and the other company is responsible for legacy System B. To conceal their identities, we will refer to these contractors simply as "ACON" and "BCON" respectively.

- ACON is the original developer of the System A avionics software. It used a traditional system development approach that resulted in a custom software implementation. The software includes major assembly code that has been extensively modified over time to accommodate government-specified enhancements.
- BCON is the original developer of the System B avionics software. Its development approach was novel. It adopted a company-proprietary product line approach, using a common software architecture and other reusable core assets, to develop the System B software. Since System B was developed after System A was operational, more complete specifications were available to develop System B resulting in significantly fewer modifications. System B software is written in a modern high order language.

Both ACON and BCON are on-site contractors. They are required to use special test facilities to integrate and test new software system builds prior to certifying them for operational use. Ideally, the SPO would like both of these legacy contractors to be involved in any future product line initiative because of their domain expertise and knowledge of the existing systems, avionics software, and test facilities.

To support its mission, the SPO uses other local contractors and an in-house engineering contingent to perform systems and software tasks such as requirements engineering, analysis, and testing.

3 Product Line Vision

In the current legacy system environment, the SPO must direct ACON and BCON to develop unique software to implement any new requirement that is common to both organizations. In effect, the government is paying twice to implement desired software changes.

In the proposed DoD ASPL, new software will be developed once, then integrated into the target avionics systems in a pre-planned and predictable manner. Thereafter, the common software will be centrally managed and sustained over the life of the product by one software organization or contractor. This is consistent with the SPO's goal to acquire a software product line capability for a family of avionics systems that can replace its existing legacy systems.

Figure 1 represents the steady-state operation of the envisioned product line following the acquisition of a product line software architecture and a start-up set of core assets.

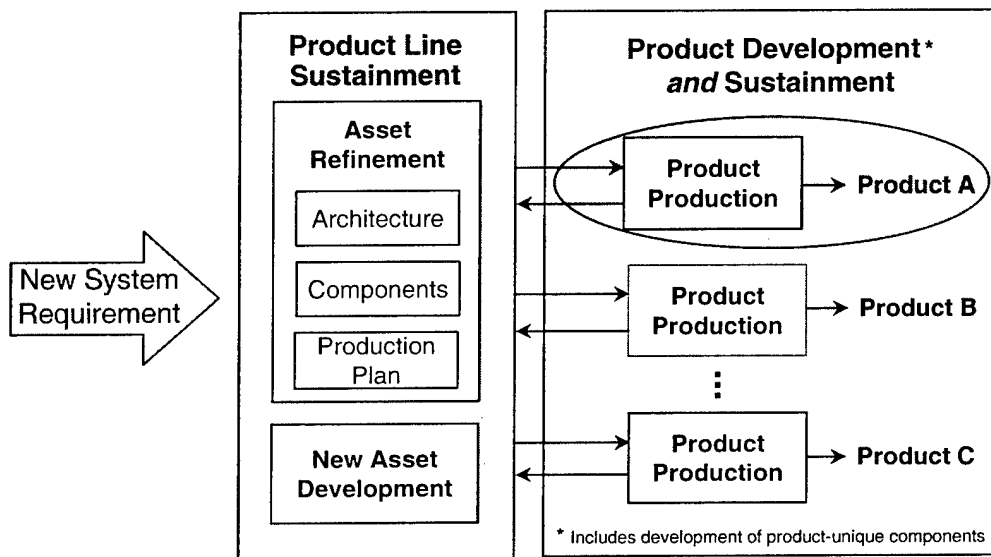


Figure 1: Responding to New System Requirements in a Product Line Approach

To achieve this vision, the SPO needed to acquire an initial product line capability. The acquisition was also to include commissioning the development of the first avionics software product having features/performance equivalent to legacy System A. This would involve mining legacy system assets to recover the functionality and mission-specific features embodied in that system. Figure 2 provides an overview of what this type of acquisition involves.

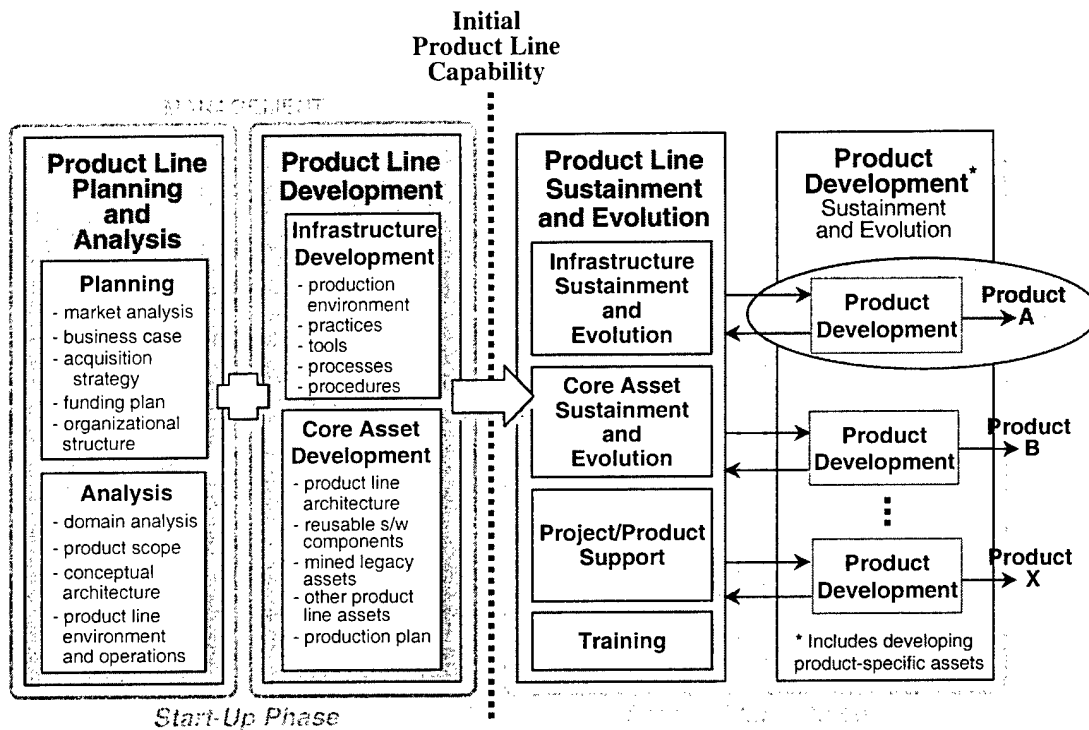


Figure 2: Conceptual View of Elements Involved in SPO's Product Line Acquisition

In keeping with this conceptual view, the SPO established three goals that were essential to its product line acquisition and the envisioned set of avionics software products:

1. **There must be a core software asset base.** These assets must cover interfaces and features in terms of requirements, architecture, components, and a production plan necessary to generate the actual products (i.e., the avionics operational software) from these core assets.
2. **There must be an efficient system integration capability.** The current approach requires too much rework to integrate new platforms, interfaces, or features.
3. **There must be a system structure to ensure cross-platform insertion of new product features.** The product line architecture, by design, must accommodate cross-platform insertion of new or changed functionality with minimal impact to current user interfaces.

Once the vision and the goals were established, the SPO formed a team to develop an acquisition strategy for acquiring a core asset base for the ASPL and for products built from it. This effort is depicted in Figure 2. In conjunction with developing an acquisition strategy, a business case was developed.¹ It compares the costs and benefits of the current way of developing software systems against those of a product line approach.

¹ The business case effort is described in a separate study [Cohen 01].

4 Acquisition Strategy Definition

Unlike industry, DoD and government organizations are required to comply with federal policy documents and regulations that govern the entire acquisition process. DoD 5000.2-R, a high-level DoD acquisition regulation, describes an acquisition strategy as being the road map “to guide program execution from initiation through re-procurement of systems, subsystems, components, spares, and services beyond the initial production contract award and during post-production support” [DoD 5000.2-R]. This acquisition strategy is event-driven and corresponds to the management approach that a Program Manager (PM) will establish for controlling and executing a major acquisition program.¹ This program-level acquisition strategy corresponds to a higher tier strategy and is significantly different than the acquisition strategy that is the focus of this case study. For example, DOD 5000.2-R contains over 100 individual requirements governing the development of an acquisition strategy.

Our definition of an acquisition strategy is more pragmatic and is applicable to any life-cycle phase of an acquisition program. We define an acquisition strategy as *a plan of action for achieving a specific goal or result through contracting for software products and services* [Bergey 99]. This definition is consistent with the Federal Acquisition Regulation and the SEI’s Software Acquisition Capability Maturity Model (SA-CMM) [FAR 97, Cooper 99]. A PM can roll this acquisition strategy into the program-level acquisition strategy. This plan of action includes all the steps required to commission (i.e., contract for) a set of core assets—chief of which is a product line architecture—and the derivative products built from those assets. This is consistent with the SPO’s goal to acquire a software product line capability for a family of avionics systems to replace the existing legacy systems, and subsequently to pave the way for incorporating future enhancements at lower cost and risk over the life of the systems.

¹ Guidance on developing such a program-level acquisition strategy is available from several sources [DSMC 99, SAMP 00].

5 Developing and Analyzing Alternative Acquisition Strategies

To address the SPO's goals for acquiring a software product line, an acquisition team was formed that included members of the SPO's staff and representatives from the operational units using the avionics systems. Team meetings were held over a two-month period and were facilitated by the SEI. The SEI representatives provided guidance and helped to structure an approach for developing and analyzing alternative acquisition strategies. The value judgments that were made in the process of analyzing and evaluating different acquisition approaches were those of the DoD organizations involved and not those of the Software Engineering Institute.

The acquisition team examined not just one, but several alternative acquisition strategies. By taking this approach, the team was able to assure the SPO's high-level management that all options were being considered and that no particular acquisition approach was being forced on them. Identifying alternatives also provided management with insight into the overall program impact of each strategy and what tradeoffs and risks were involved.

The following steps summarize the approach that the acquisition team took to develop a software product line acquisition strategy:

1. Understand the motivation for the product line initiative and its scope.
 - a. determine the sponsor's vision and goals for the product line acquisition
 - b. understand the product line scope and its relationship to any baseline legacy systems that will eventually be supplanted by future products from the product line
2. Capture management guidance and planning assumptions that will guide or constrain the product line acquisition.
3. Explore candidate acquisition approaches that can satisfy the product line vision and acquisition goals commensurate with the product line scope and other relevant management guidance and planning assumptions.
4. Establish the major programmatic and technical drivers that will govern the acquisition approach and ultimately determine its suitability.
5. Analyze and evaluate the efficacy of each candidate course of action using the major drivers identified in the previous step.
6. Recommend a product line acquisition strategy and develop a corresponding plan of action for pursuing the strategy.
7. Produce a report summarizing the findings and recommendations so that higher level management can determine whether the recommended acquisition strategy best satisfies the organization's needs.

5.1 Understanding the Product Line Acquisition Context

Accomplishing the first step involved eliciting and understanding the background information described earlier in Sections 2 and 3. The process consisted of attending briefings that described the organization's planning and analysis effort for the product line initiative and having follow-up discussions. These briefings relied heavily on the expertise of the individuals who previously conducted the product line scoping effort [Cohen 01]. The individuals gave the acquisition team a good understanding of the SPO's vision and goals for the product line. They also described the product line scope and its relationship to current legacy system baselines.

5.2 Establishing Acquisition Guidance and Planning Assumptions

Having obtained this background information, the team next captured guidance provided by SPO management and documented any planning assumptions pertinent to the acquisition. Table 2 summarizes some examples of management guidance and planning assumptions.

Table 2: Guidance and Planning Assumptions for SPO's Product Line Acquisition

Example Guidance/Planning Assumptions	
1.	Product line effort will focus on delivering a product with System A functionality within three years.
2.	Any loss of System A core features/functionality is not acceptable (i.e., performance is a given).
3.	Product line approach must accommodate System A user interface compatibility.
4.	All embedded mission computers will be replaced coinciding with initial product delivery.
5.	Since effort is not aligned with other programs, new funding sources must be pursued.
6.	One potential source of funding for the product line initiative is currently a line item in the POM.
7.	Current legacy system Post Deployment Software Support (PDSS) contracts will remain in place.
8.	Incumbent contractors can perform supporting technical analyses under existing PDSS contracts.
9.	The System B legacy software is proprietary (i.e., owned by the development contractor) but the government owns the rights to the System A legacy software.
10.	The SPO will seek government data rights to all product line software assets including the architecture.
11.	All products must be deliverables to the government regardless of the acquisition strategy chosen.
12.	Future avionics enhancements are beyond the scope of the initial System A product development.

Explicitly recording the guidance and assumptions was a necessary step to ensure that the acquisition team was "on the same page" as management and had a common understanding of the expectations and ground rules for the product line acquisition.

5.3 Developing Candidate Courses of Action

The acquisition team considered various contracting approaches for acquiring a product line. This involved exploring tradeoffs between using fixed-price, cost reimbursement, incentive, indefinite delivery, time and materials, labor hours, letter contracts, and even basic ordering agreements. These constitute the range of permissible types of contracts as described in Part 16 of the Federal Acquisition Regulation (FAR). The FAR provides general guidance and outlines the conditions for using each of these different types of contracts. Since the FAR governs all DoD and government acquisitions, every acquisition strategy must use one (or a combination) of these basic types of contracts and award fee structures.

After strategizing and considering the pros and cons of various approaches, the team devised four basic contractual approaches that could potentially fulfill the SPO's goals for acquiring a software product line. These four basic contractual approaches (i.e., Pre-Qualify, Sole Source, Fly-Off, Open Acquisition) translated into five candidate courses of action (COAs) that are summarized in Table 3.

Table 3: *Candidate Courses of Action (COA) for Acquiring a Product Line*

Candidate Courses of Action (COA)		
ID	Descriptive NAME	Contractual Approach
COA # 1	PRE-QUALIFY multiple contractors awarded contracts and collaborate in effort	Competitive award of 2 or 3 task order contracts to multiple offerors to collaborate in product line and product development (i.e., an avionics software system) in accordance with pre-established source selection criteria.
COA # 2A	SOLE SOURCE to ACON: System A software contractor	Sole source award of a single task order contract to one of the incumbent software contractors to develop a software product line and a baseline product. These two mutually exclusive choices are explored to consider the impact of one legacy software contractor being selected over another.
COA # 2B	SOLE SOURCE to BCON: System B software contractor	
COA # 3	FLY-OFF resulting in award of single contract to best-value performer	Competitive award of two or three short term contracts. Have selected offerors compete in a "fly-off" development effort leading to the award of a single task-order contract to the offeror demonstrating "best value" performance.
COA # 4	OPEN Acquisition single contract award	Competitive award of a single task order development contract to the offeror ¹ submitting the "best value" proposal.

¹ It is an offeror's prerogative to represent a single contractor or a contractor team.

Each of these COAs is compatible with commissioning a product line capability, including a product line architecture, common software components, and other core assets required to build a family of software products. The first avionics software product to be acquired would have features and performance equivalent to legacy System A. The design of the core assets would support the software commonality and variability of other planned avionics software products that are within the product line scope.

The common denominator for all of these COAs is a contracting approach based on an indefinite delivery/indefinite quantity (ID/IQ) task order contract. An ID/IQ task order contract is the best fit since the exact times and quantities of future deliveries are unknown and there is a recurring need for services. With other contract types, the SPO would have to commit to more than a minimum quantity and additional funding would be required at the time of contract award. This could significantly increase the acquisition risks and create funding problems. The ID/IQ task order contract also allows for other risk mitigation measures to be easily included. We will present these in a later section.

5.4 Identifying the Major Acquisition Drivers

To assist in analyzing and evaluating which course of action might be the most effective, the acquisition team identified a number of crucial acquisition drivers. These major drivers are the key programmatic and technical considerations that will direct the course of the acquisition and, ultimately, determine the suitability of one approach over another.

Table 4 lists a set of major drivers used in this case study. All of these drivers fell in the category of being essential or highly desirable. Their order generally reflected the SPO's relative priorities and concerns.

Table 4: Major Drivers Used to Analyze Impact of Candidate Courses of Action

Major Acquisition Drivers	
1.	Contractor(s) will have access to all legacy software.
2.	Contractor(s) will have relevant expertise to be able to leverage GFI ¹ legacy software.
3.	Acquisition approach will have the potential to involve both legacy system contractors.
4.	Contractor(s) will be totally responsible for avionics software performance.
5.	Acquisition approach will be compatible with schedule constraints.
6.	The SPO can acquire government-use data rights for all product line assets.
7.	Acquisition approach will reduce risk of acquiring a product line capability.
8.	Likelihood of being able to avoid a protest that could impact acquisition schedule
9.	SPO's perception of the affordability of the approach (based on historical cost data)

¹ The System A software would be provided as a Government Furnished Item (GFI) to the product line development contractor who is awarded the contract.

In effect, these major acquisition drivers represent the criteria for analyzing the suitability of the candidate courses of action and indicate some of the acquisition tradeoffs that are involved. Therefore, it was important that the team have a common understanding of these drivers and how they could affect the acquisition. To facilitate this understanding, the team diligently discussed and described each of the drivers. These descriptions provided insight into the nature of the need, or concern, that the acquisition driver is addressing. Several examples follow:

- Driver #1. Contractor(s) will have access to all legacy software.

The SPO does not have data rights to the System B legacy software. As a result, another contractor cannot be given the System B source code to extract the functionality, design, or operation of that system. On the other hand, the government owns System A software and can provide it to another contractor as a government-furnished item (GFI). Ideally, the product line contractor should have access to *both* the System A and System B legacy software if it is to implement a product line approach (based upon current capabilities) in a timely and cost-effective manner. Only the System B contractor potentially has access to System B legacy software. Even its use on a different contract may require company approval.

- Driver #2. Contractor(s) will have relevant expertise to leverage GFI legacy software.

The issue is whether the winning contractor will have the domain expertise, technical skills, tools, and experience needed to effectively leverage the existing System A software. The SPO anticipates that any contractor other than the incumbents will have a steep learning curve and may not be able to effectively leverage the GFI System A software. Even System A contractor may face a challenge in leveraging the assembly-level code that is part of its own software because it was developed independently by a sub-contractor. The objective in leveraging the GFI software is to accurately capture System A functionality¹ so that a set of reusable software components (and related assets) can be developed that are fully compatible with a product line approach and faithfully replicate the capabilities of System A software. Another objective in leveraging the existing code is to implement an equivalent capability at a cost and schedule less than that required for a start-from-scratch development effort.

- Driver #3. Acquisition approach will have the potential to involve both legacy system contractors.

It would be ideal if both legacy system contractors were collaborating on the development of a product line capability. This is due to the fact that one contractor has

¹ The term "functionality" is used in a very general sense as fully encompassing the current capabilities and features of the System A software.

specialized knowledge of and experience with product lines and product line architectures, while the other contractor has unique knowledge of and experience with the System A software that is the “avionics system of choice.” However, since the government cannot force a collaborative/teaming relationship, it can only promote the possibility of such an arrangement by the way it structures the acquisition.

- Driver #6. SPO can acquire government-use data rights for all software assets.

Acquiring government-use data rights for all software assets is desirable for three very important reasons:

- First, it can avoid a situation in which one contractor (e.g., BCON) has a virtual lock on software life-cycle support.
- Second, it will enable the government to have other contractors independently develop and integrate software into other mission critical subsystems and technologies in the product line family of systems.
- Third, in the future, it will potentially enable the government to provide the software to other contractors to competitively develop new product line assets (e.g., reusable software components) and support new mission requirements (i.e., extend the product line). One cautionary note is that a contractor may be very reluctant to sell government-use data rights if it believes that other contractors will obtain visibility into their proprietary product line operations and core assets. Such an arrangement could potentially compromise the contractor’s competitive edge in the marketplace. In these cases, contract negotiations may provide the only avenue that could lead to an acceptable solution.

5.5 Analyzing and Evaluating the Candidate Courses of Action

In this step of the process, the team meticulously analyzed the five candidate courses of action. This involved evaluating the potential ability of each course of action to satisfy the major drivers identified in the previous step. The acquisition team members relied on their corporate knowledge and expertise on the subject matter, historical data, and common sense to perform the analysis and reach a consensus. The team used Red (R), Yellow (Y), and Green (G) indicators to summarize the findings and present them to upper management. These indicators are explained below:



Indicates that the candidate COA will probably **not** satisfy the acquisition driver.











Indicates that it is marginal or questionable whether the candidate COA can satisfy the particular acquisition driver. These concerns (i.e., yellow indicators) potentially may be satisfied, or overcome, via the contract negotiation process. However, if they are not resolved some of them they potentially may become “show-stoppers” corresponding to red indicators.



Indicates that the candidate COA will most likely satisfy the acquisition driver.

Table 5 summarizes the analysis of all the COAs. It indicates the projected effect of the major acquisition drivers on each candidate course of action.

Table 5: Summary of Impact of Acquisition Drivers on Candidate COAs

	PRE-QUALIFY	SOLE SOURCE		FLY-OFF	OPEN Acquisition
Business/Acquisition Drivers	COA #1	COA #2-A A CON	COA #2-B B CON	COA #3	COA #4
1. Contractor(s) will have access to all legacy software.	(Y)		(G)		
2. Contractor(s) will have relevant expertise be able to leverage GFI (ACON) software.	(Y)	(G)	(Y)	(G)	(Y)
3. Acquisition approach will have potential to involve both legacy system contractors.	(G)			(Y)	(Y)
4. Contractor(s) will be totally responsible for avionics software performance.		(G)	(G)	(G)	(G)
5. Acquisition approach will be compatible with schedule constraints.	(Y)	(G)	(G)	(Y)	(Y)
6. The SPO can acquire government-use data rights for all product line assets.	(G)	(G)	(Y)	(G)	(G)
7. Acquisition approach will reduce risk of acquiring a product line capability.	(Y)	(Y)	(G)	(G)	(Y)
8. Likelihood of being able to avoid a protest that could impact acquisition schedule	(G)			(G)	(G)
9. The SPO's perception of the affordability of approach (based on historical cost data)	N/A	(Y)	(G)	N/A	N/A

A brief explanation of each red and yellow indicator was included with the summary. For this technical note, we will explain the rationale for one of the Red indicators, driver #4 under COA #1.

COA #1 (PRE-QUALIFY)—Since this strategy involves awards to multiple contractors, no single contractor will have total responsibility for the performance of the avionics software product. Instead, the government will have de-facto responsibility and “finger pointing” among contractors can be expected should problems arise.

It is important to point out that no one course of action will satisfy all the drivers as all the COAs involve significant tradeoffs. For example, if the selected course of action involves multiple contractors, as in COA #1, then clearly, no single contractor will have total responsibility for all the contractual work. Consequently, the SPO has to tradeoff the desire to have both incumbent contractors involved (because of their extensive knowledge of the legacy software) against the desire to have one contractor assume total responsibility for the system.

The cost driver (i.e., the SPO’s perception of the affordability of the proposed COA) is only applicable to COAs #2A and #2B because historical cost data exists only for these options that directly relate to the existing legacy software contractors.

5.6 Recommending an Acquisition Strategy and Establishing a Plan of Action

In this case study, the acquisition team did not recommend a particular course of action. Instead, due to the sensitive nature of the acquisition and the tradeoffs involved, it reported on all the candidate courses of action with the understanding that management would make the final decision. Tradeoffs needed to be considered because there were compelling arguments for selecting a sole source acquisition strategy and compelling arguments for selecting a competitive acquisition strategy. For example, the following arguments could be made for selecting COA #4:

- promotes open competition
- is consistent with a tight schedule
- is potentially the lowest cost approach
- offers the most balanced approach for meeting the organization’s stated goals
- is the least likely course of action to result in a protest

However, all the COAs offered unique benefits and all of them (including COA #4 cited above) included at least one red indicator:

- COA #1. No single contractor would have total responsibility for the end-product.

- COA #2A and #2B. The risk of a contractor filing a protest is higher and that could adversely impact the schedule.
- COA #3. Despite its desirability, a competitive fly-off involves extra time and costs and is incompatible with the program's cost and schedule constraints.
- COA #4. Contractors will only have access to the GFI software and not the CMS software that reflects a product line approach.

As a result, SPO management requested that the acquisition team brief them on each COA.

Defining a Plan of Action

Had the team recommended a course of action, the next step would be defining a plan to carry it out. The following example plan of action applies to the open competition acquisition strategy (e.g., COA #4) and consists of six steps:

1. The SPO will task the legacy contractors (under their existing contracts) to jointly define a conceptual architecture for the software product line and develop a requirements specification for the DoD ASPL.
2. In parallel with Task 1, the SPO will form an ASPL Integrated Project Team (IPT) to refine the product line scope, specify the conceptual architecture, develop the requirements specification, and gather the documents that will be provided as GFI.
3. After Task 1 is complete, the ASPL IPT will analyze the deliverables produced under Task 1 and selectively integrate those elements that will enhance and elaborate the work products developed under Task 2. *[This will assist the SPO in developing a more complete and robust specification that will reduce the risk of having to amend the RFP during the solicitation period and enhance the likelihood of acquiring a higher quality product.]*
4. In parallel with the preceding tasks, the acquisition team will develop an acquisition plan for an open competitive procurement using an ID/IQ contracting approach, and execute the plan. The acquisition plan will refine the acquisition strategy, develop a work breakdown structure describing the acquisition tasks, and develop a detailed schedule with measurable milestones. *[This will assist the SPO in achieving an action-oriented acquisition strategy, ensure everyone is on the "same page," enhance the team's ability to stay focused and develop the RFP on schedule, and meet the organization's overall acquisition goals.]*
5. The acquisition team will integrate the enhanced work products developed by the ASPL IPT into the RFP, complete Sections C, J, L, and M of the RFP¹, and develop a source selection plan. *[This will complete preparation of the RFP and enable the Contracting Officer to begin the formal solicitation.]*

¹ Sections C, J, L, and M correspond to the Statement of Work (SOW) and Specifications, List of Contract Deliverables, Proposal Preparation Instructions, and Evaluation Factors for Award, respectively.

6. A source selection team will evaluate the offerors' proposals (in accordance with the source selection plan) and competitively award a single contract to develop the DoD ASPL capability and common architecture leading to the delivery of a new version of System A using the product line architecture and components. *[This will complete the award phase and begin the contract management and performance phase that will lead to the development of the specified contract deliverables. Having a rigorous acquisition plan and a judicious source selection plan will reduce the risk of any bona fide protest being filed by an offeror.]*

Developing a plan of action for a different acquisition strategy would involve adapting elements of this plan of action.

5.7 Preparing an Acquisition Strategy Summary Report

The last step consisted of documenting the findings and presenting them to management for review and approval. In this case study, all the candidate acquisition courses of action were presented to management since the team was not asked to recommend a specific one, but rather to present the pros and cons of each. The acquisition team was aware that the management review was going to be more than perfunctory. In fact, management ultimately chose a different acquisition strategy based on extenuating circumstances that were beyond its control and changed the scope of the acquisition.

The acquisitions team's report included much of the same information as presented in this technical note. An explanation of the team's findings and a management presentation were built around the tables presented here. The description of each candidate course of action included an explanation of each red and yellow indicator to clarify the nature of the impact.

Once management approves an acquisition strategy, implementing the strategy will often involve two teams as outlined in the hypothetical plan of action above. Ideally, an acquisition team should be formed to have overall responsibility for planning all aspects of the acquisition and integrating all the sections that make up the complete RFP. An Integrated Project Team (IPT) should be responsible for performing the supporting technical analyses and developing the required specifications that will be included in the RFP. Section C (*Statement of Work and Specifications*) of the RFP would identify the product line related tasks to be performed by the contractor(s)—commensurate with the chosen acquisition strategy—and include the performance specifications for the avionics software product(s) to be developed. Developing robust specifications and a comprehensive RFP are critical to the success of the entire project. They can substantially reduce the risk of having to amend the solicitation, which can otherwise result in a long and protracted contract award.

6 Acquisition Strategy Risk Mitigation

There are obvious benefits and risks to each of the candidate approaches. However, several concerns surfaced in this case study: “Can a contractor other than the original developer successfully replicate the System A software (i.e., redevelop the software from the original source code¹) commensurate with a product line approach and modern software practices?” and “Can measures be taken to insure that if a contractor falters it can be detected in the early stages of development before a substantial amount of funds have been expended?” From the SPO’s perspective, this was the essence of the risk of adopting a product line approach—especially when considering a competitive acquisition.

Fortunately, there are innovative measures that can be taken to mitigate these risks and allay any concerns of being irreversibly trapped into one course of action should a contractor falter. Some of these are presented below:

- Negotiate a first task-order² under each contract concurrent with contract award for a relatively small sum corresponding to the declared contract minimum.
- Include a number of pivotal tasks in this first task-order that will demonstrate the contractor’s ability (or inability) to perform the critical tasks required to mitigate high risk items that are of particular concern to the SPO.
- Specify tasks in the first task-order that will result in tangible deliverables that can be evaluated by a technical agent of the contracting organization to determine their suitability or unsuitability.
- After evaluating the incremental deliverables produced under the first task-order, decide whether another follow-on task-order, similar to the first, should be initiated before fully committing the SPO’s resources to the current acquisition strategy.

These measures can be applied to any of the candidate courses of action³ as long as they are ID/IQ task order contracts. It should be noted that the government always has the right to terminate a contract either on the basis of termination-for-convenience⁴ or termination-for-default.⁵ In the risk mitigation scenario outlined above, the government doesn’t need to

¹ The original source code is reported to be a combination of JOVIAL and assembly language.

² The government does not have to commit to give a contractor more than one task order.

³ It may, however, be more difficult to negotiate such an agreement for a sole source acquisition.

⁴ Termination-for-convenience is known as “T for C” and is invoked when the objective is determined to be unachievable because of problems due, at least partially, to the government. In these cases the government must reimburse the contractor for the effort that has already been expended.

⁵ Termination-for-default is known as “T for D” and can be invoked if it has been determined that the contractor can’t meet the requirements. The amount of money the contractor is entitled to may be negotiated at the discretion of the contracting officer but it will not exceed the cost of the effort that has already been expended.

terminate the contract should a problem arise. The government is only obligated to fund the minimum task order that the contract specifies. This can be defined in terms of some minimum dollar amount, a number of discrete tasks and deliverables, or hours of effort commensurate with the program's resources and risk management approach. By performing the initial task order(s), the contractor can conclusively demonstrate its ability to perform crucial tasks and mitigate high risk items without requiring the government to irrevocably commit its resources up-front. If approved, the acquisition team would incorporate these measures into the acquisition strategy.

7 Summary

We have outlined the approach that one DoD organization used to develop an acquisition strategy for acquiring a software product line to eliminate the need to maintain two independent baselines and pay twice for developing new software capabilities. The approach used consists of seven steps that other organizations potentially can adapt to develop their own acquisition strategy.

As part of this effort, the acquisition team analyzed four basic acquisition approaches and five candidate courses of action leading to management's selection of an acquisition strategy. These candidate COAs could potentially apply to any acquisition strategy used to commission a software product line. The case study includes an innovative risk mitigation approach that is also suitable for any acquisition strategy using an ID/IQ contract.

References

- [Bergey 99]** Bergey, John; Fisher, Matthew & Jones, Larry. *The DoD Acquisition Environment and Software Product Lines* (CMU/SEI-99-TN-004). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, WWW: <URL: <http://www.sei.cmu.edu/publications/documents/99.reports/99tn004/99tn004abstract.html>> (May 1999).
- [Clements 00]** Clements, Paul & Northrop, Linda. *A Framework for Software Product Line Practice*, Version 3.0 [online]. Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University. WWW: <URL: <http://www.sei.cmu.edu/plp/framework.html>> (Sept. 2000).
- [Clements 99]** Clements, Paul. "Software Product Lines: A New Paradigm for the New Century." *Crosstalk* 12, 2 (February 1999): 20-22.
- [Cohen 01]** Cohen, Sholom. *Case Study: Building and Communicating a Business Case for a DoD Product Line* (CMU/SEI-2001-TN-020). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, WWW: <URL: <http://www.sei.cmu.edu/publications/documents/01.reports/01tn020.html>> (June 2000).
- [Cooper 99]** Cooper, Jack; Fisher, Matthew & Sherer S. Wayne. *Software Acquisition Capability Maturity Model* (SA-CMM), Version 1.02 (CMU/SEI-99-TR-002 ADA362667) [online]. Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University. WWW: <URL: <http://www.sei.cmu.edu/publications/documents/99.reports/99tr002/99tr002abstract.html>> (April 1999).
- [DoD 5000.2-R]** Interim DoD Regulation 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs* [online]. U.S. Department of Defense. WWW: <URL: <http://www.acq.osd.mil/ar/ar.htm>> (October 23, 2000).
- [DSMC 99]** *Acquisition Strategy Guide, 4th Edition*. The Defense Systems Management College Press. Fort Belvoir, VA: Available WWW: <URL: <http://www.dsmc.dsm.mil/pubs/gdbks/asg.htm>> (December 1999).

[FAR 97]

Federal Acquisition Regulation, FAC 97 [online]. WWW: <URL:
<http://www.arnet.gov/far>> (October 10, 1997).

[SAMP 00]

Single Acquisition Management Plan (SAMP) Guide [online]. U.S.
Department of the Air Force, June 14, 2000. WWW: <URL:
http://www.safaq.hq.af.mil/acq_ref/bolts/bolt7/> (June 14, 2000).

Feedback and Contact

Comments or suggestions about this document or the series of technical notes on software product line business and acquisition guidelines are welcome. We want to meet the needs of DoD and government personnel involved in the business and acquisition aspects of implementing software product lines. To that end, comments concerning this technical note, inclusion of other topics, or any other issues or concerns will be of great value in continuing this series. Comments or suggestions should be sent to

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